

The integration of smart features will: 1) allow only authorized patients access to their pills (only) at the right time and at the correct dosage; and 2) allow the prescriber and pharmacist to observe data generated by these sensors to remotely monitor product removal and help support pain management.

[0030] Bottle 21 of FIG. 1A secures a bottle-cap 25 with fingerprint recognition technology using a single RGB camera 28 equipped with a standard CMOS sensor through which the colored images of persons and objects are acquired. A Frustrated Total Internal Reflection (FTIR) finger print image is captured by the user placing his or her finger on a right angle prism 29. The fingerprint is illuminated using an array of white light LEDs 32. Fingerprint recognition is performed using an on-board microprocessor 34. A container body 35 of the bottle is secured against physical tampering by integrating a dual-walled layer including a water solution of aversive compound 36. A compartment vial 38 of container body 35, between the dual walls will release the aversive compound on pills 23 inside bottle 21 upon tampering with the bottle, which will render the pills unconsumable. Bottle-cap 25 is attached to the bottle body 35 using a hinge 37 and a biometric controlled locking mechanism 43. The on-board microprocessor is powered using a non-rechargeable battery 49 in container body 35 on cap 25.

[0031] A second embodiment bottle 121 of FIG. 1B replaces the right-angle glass prism in FIG. 1A with a thin glass sheet 123. Bottle 121 of FIG. 1B comes equipped with a dual camera 124 and 126 setup mounted back-to-back to each other. Camera 124 is pointing upwards to capture a direct view 126 is fingerprint image of the finger placed on thin glass sheet 123 mounted on a removable cap 125. Camera 126 is pointing downward to image contents of a container 135 of bottle 121, which is then processed to count the number of pills 23 in the bottle. A hinge 137 and locking mechanism 143 of the FIG. 1B embodiment are also equipped with weight sensors 145 for measuring the weight in the bottle (discussed in greater detail hereinafter with regard to FIG. 6), which augment the pill counting mechanism based on the image captured by camera 126. The bottle comes equipped with Bluetooth and NFC technologies, which it uses to pair with any smartphone device 147 for utilizing its computing resources for analyzing the bottle's usage statistics.

[0032] Unlike the version of FIG. 1A, the present exemplary FIG. 1B bottle uses a wireless charging pad 110 for powering its on-board microprocessor 134. The wireless charging pad can further draw power from a power supply 112, such as a wall socket or a portable battery bank. A base or bottom 151 of the bottle is equipped with a compatible wireless charging coil 111 as shown in FIG. 2B.

[0033] The sensing and computation procedure requires DC power, which is usually obtained from batteries. However, use of a battery would make the pill bottle bulky in size and impose a recurring cost. Hence, an RF power harvesting mechanism, such as coil 111, is implemented at the bottom part of the pill bottle, preferably as a high-density coil. A detailed block diagram is shown in FIG. 3 for the wireless charging and the energy harvesting. Bottom coil 111 receives the AC signal with mutual coupling of the coil. The signal is rectified in the diode rectifier bank to convert AC into DC power. However, the generated DC is unregulated and needs a voltage regulator for a regulated supply. Once

the regulated power is generated, it can power up the processing unit, the MCU and other sensors.

[0034] Referring to FIG. 1C, a software-enabled bottle 221 contains multiple sensors namely: an RFID sensor 261 (see FIG. 4B), an optical sensor using a camera 224 and a weight measurement sensor 245. The model of FIG. 1C has all the features of the model of FIGS. 1 and 9B. The FIG. 1C bottles 221, however, are additionally equipped with Wi-Fi technology, including a transmitter and receiver 263 mounted to the bottle, and can connect to the internet. Therefore, the bottles can be remotely monitored and controlled by healthcare professionals or caregivers 264 via a monitor station 267. Also, this bottle 221 comes equipped with a circular array of far-field microphones and a speaker unit 215 mounted on top of the bottle cap 225. Microphone-speaker unit 215 is used to operate a voice based digital assistant on the bottle itself. The digital assistant can assist a user 226 with correct usage of the bottle and can provide an additional layer of biometric security using voice recognition technology.

[0035] RFID sensors 261 are mounted to cap 225. Furthermore, an electrical circuit 265 of a lockout mechanism 243 with a processing unit 234 is shown in FIG. 5. The processing unit is responsible for obtaining necessary information from the sensors and activates lock 243 upon authorization. The lock out is an electromagnetic lock mechanism 243 having a small size and an electronic control.

[0036] The basic block diagram of the RFID sensor is shown in FIG. 5. The sensing unit consists of two parts: 1) an RFID reader 265, and 2) an RFID card 267. The RFID card has the ID, which is read by the reader. Reader 265 is installed on top of cap 225 of the pill bottle along with a processing unit 234. The bottle verifies each user with a valid RFID 267 card and provides acknowledgement signal to processing unit 234 for opening a push-pull lock 343 (see FIG. 4B) which is operably received in a hole 269 (see FIG. 4C) in an outer wall of container 235 at an optional reduced diameter neck. The reader has a RF oscillator 271, which generates the RFID frequency. The low power RF signal is amplified by a power amplifier 273 and transmitting coil 261 is excited. To miniaturize the system, the transmitting coil is designed around cap 225. If an RFID card is present within the electromagnetic field, a perturbation is observed, which is compared at a comparator 275 with a reference voltage 277. The sequence of ID is read and sent to microcontroller unit (MCU) 234.

[0037] Also a weight sensor 145 is implemented as shown in FIG. 6 to estimate how many pills 23 are dispensed and/or to prevent drug abuse. For this, a piezo resistive based thin film is inserted in between pill container 235 and a pill bottle bottom 251. The piezo film changes the RFID sensor circuit architecture based on its resistance according to pressure applied on it. From the resistance of piezo film 145, an estimate of the number of pills 23 is obtained. The resistance is measured by processing unit 234.

[0038] Reference should now be made to FIGS. 7, 8A-F and 9 to understand the anti-tampering features of the present bottle 321. The present embodiment of this bottle device 121 combines RFID sensor, biometric authentication sensors, and a lockout mechanism that secures prescribed drugs 23 and prevents unauthorized individuals 301 from accessing them. This smart pill device prevents young children and adolescents from accessing pills found at home. To make it able to divert force—induced package-tamper-